Magnetic resonance on oriented 131I nuclei in iron. A study of magnetization behaviour, implantation damage and nuclear spin-lattice relaxation in iron single crystals.

Visser, Derk

SUMMARY

In this thesis we describe experiments on ^{131}I implanted into iron single crystals. At low temperatures the nuclei, experiencing a hyperfine field coupled to the local direction of magnetization of the iron, will orient themselves. From the angular distribution of the emitted γ-radiation one can derive the state of magnetization of the sample. We have shown that the magnetization behaviour of iron single crystals in an external magnetic field agrees with the macroscopic theory of domain structure in ferromagnets.

This knowledge is used to give the influence of the external field on NMR measurements on the iodine. The resonance is observed by detection of the γ-radiation. The iodine atoms that end up in regular lattice sites after the implantation give rise to a strong resonance. This was first found in Oxford.We report on the discovery of a much smaller sattelite resonance, due to I nuclei experiencing a hyperfine field of 92% of that of atoms in regular lattice sites. The splitting of this resonance by quadrupole interaction has enabled us to identify it as due to an implanted iodine atom with a missing nearest neighbour iron atom. With the aid of an annealing study, it is shown that only $\sim$ 9% of the implanted atoms end up in this site. There is evidence that a fraction of $\sim$ 24% of the nuclei, that also experience a large hyperfine field, have not (yet) turned up in the NMR spectra.

Normal resonance experiments yield the static interaction of the nucleus with its surroundings. Nuclear spin-lattice relaxation, on the other hand, is determined

by the dynamic interaction. We have measured the relaxation of the iodine nuclei in iron single crystals for different crystallographic orientations. For the first time it is shown that the relaxation rate depends strongly on the magneto-crystalline anisotropy; a high rate results at a low external field. This behaviour can not be explained with the relaxation mechanisms,discussed in the literature up till now.

It is very likely that the low-field spin-lattice relaxation is largely determined by spin wave interactions, which are strongly field dependent. We have derived the anisotropic dispersion relation for these waves, including the dependence on the state of magnetization of the sample. A calculation of the first order process, in which a spin wave is created by a nuclear spin flip, showed that it gives a contribution to the relaxation rate about an order of magnitude too small to explain the measurements. A second order process, in which the spin waves act as an intermediary, looks more promising. The method to calculate the associated relaxation rate is indicated.

Finally a simple method is given to measure the power saturation of an NMR-ON resonance, from which the fraction of nuclei contributing to this resonance can be derived.